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Automatic Change Detection from Remote Sensing Stereo Image for Large Surface Coal Mining Area

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Abstract

Surface mining activities may cause the significant change of the topography and stability of landscape, which may lead to a series of environmental issues, such as water runoff, soil erosion and vegetation degradation. Thus, the characteristic of artificial landscapes should be concerned for reconstruction of mining ecosystems. Remote sensing imagery, particularly stereo image with the advantage of generating digital elevation model (DEM) efficiently can provide information of topography from the surface mining area. The purpose of this study is to monitor topographic change using remote sensing stereo image in large surface coal mine. In this study the ASTER stereo imageries collected in 2002 and 2006 were used to generate DEM. Quantitative methods such as the RMSE and topography profile were conducted to evaluate the accuracy of the ASTER DEM based on the reference 1:50000 topography map. Furthermore, the change of topographic which can be detected were developed based on the image difference by setting a threshold value and watershed transform method. The results indicated that: root-mean-square errors (RMSEs) in elevation are 25m for ASTER DEM in 2002, and 26m for ASTER DEM in 2006. The topographic change from open pit at 2002 and dump at 2006 was automatically and accurately detected, which provided quantitative information for exploiting-peeling-deserting unification of mining. Such piece of information would be very useful in mining rehabilitation and ecology restoration.

Keywords

Large Surface Mine; ASTER-DEM; Topographic; Change Detection

Introduction

Surface mining activities include exploration, development, and mine construction, each of these phases may cause significant change of the topography and stability of landscape[1]. Thus, reconstruction of various ecosystems is being guided by the changed characteristics, changed trends and landform factors of artificial landscapes[2]. A stable landform with a self-sustaining vegetation cover is a primary goal for mine rehabilitation[3]. A successful monitoring approach for evaluating surface processes, including landform changing and reconstruction at a regional scale requires observations with frequent temporal coverage over a long period of time.

Currently, high resolution stereo remote sensing image is capable of generating grid-based digital elevation models (DEMs), which are extensively and routinely used in visual and mathematical analysis of topography, landscapes and landforms, as well as modelling of surface processes[4, 5]. ASTER stereo image, which can generate DEM, would be suitable for environmental mapping tasks with accuracy between ±7m and ±15m of the four study areas around the world[6, 7]. Topographic change detection is an emerging tool in geomorphology[8], where a raster grid of topography from one period is subtracted from another period with the resulting difference indicating the locations and magnitudes of landform change. In large surface mining site, the topographic change detection can provide the basis for the soil erosion prevention and water loss reduction effectively[9]. Due to the limitation of multi-date DEM data at large scale, the topographic change monitoring has not been widely applied for ecological

restoration and land rehabilitation for surface mining site.

Therefore, this study aims to 1) evaluate the potential and limitation of remote sensing stereo imagery of ASTER DEMs in terms of the landform change monitoring for large surface mining site; 2) automatically identify and quantitatively analyze decadal-scale topography changes from surface mining to artificial landform reconstruction.

Study area and remote sensing image

The Aaitaibao (ATB) open-pit coal mine lies in the northern of Shanxi province, Central China (Fig.1), with an area of 60 km2. The natural topography was characterized by gullies and ridged hills with elevation between 1200m and 1350m above the Loss Plateau. The ATB open-pit coal mine started mining in 1987. At the time, the landscape was characterized with dump, open pit, mining and industrial area (Figure 2). Most of the landscape in the minefield was further reshaped by digging and dumping.

The ASTER stereo images (Level 1A) were collected in October, 2002 and October 2006 covering the entire mining site. The ASTER stereo images covering the study area were geo-referenced to the UTM coordinate system resulting in a root-mean-squared error of 0.5 to 1.0 pixels. In order to valid and assess the accuracy of the two ASTER-DEMs, the topographic maps with scale 1:50,000 acquired by aerial photo in 2005, which converted to DEM data, was used as reference data.

Methodology

Generation of DEM based on the stereo images can be performed with ENVI- DEM Extraction Module. The ground control points (GCP) were defined interactively. Map (x, y, z) coordinate values were getting from topographic maps (1:50000 and 1:2000). Subsequently, the tie points were generated automatically using the DEM Extraction model in ENVI5.0. 70 tie points were edited and checked, which error rank was above the upper limit, and added 30 new tie points interactively in the left and right images. As the result, 100 tie points were collected for the ASTER stereo images. Finally, DEMs of study area were generated.

There were two ways including vertical and horizontal precision for basic accuracy assessment. The validation was performed in terms of RMSE. The topographic profiles were used to evaluate the accuracy of ASTER on horizontal level.

Setting of a threshold value and topographic profile were applied to evaluate the changes in elevation. Image differencing was considered as a mean to provide confirmation of the topographic change, and a spatial context of the region of change for profile-based elevation change measurements[10]. Furthermore, the different level of the two ASTER-DEMs was classified to get the changes in elevation by setting a threshold value. In horizontal plane, the watershed transform was used to analyse the change. The watershed transform was used to look for the catchment basins and ridge lines in a grey-scale image. The watershed transform was applied to mark the boundaries of catchment regions to get the changes in the horizontal plane based on different maps.

Result and Discussion

DEM Generation

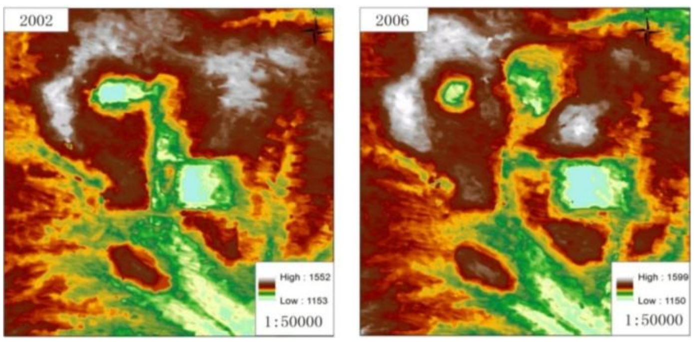


FIG. 1 DEMS DERIVED FROM ASTER STEREO IMAGES IN THE STUDY AREA

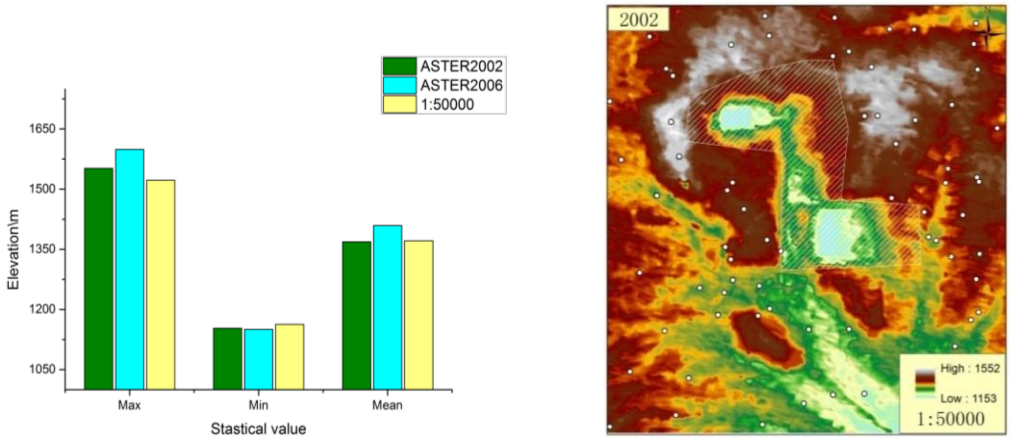
As shown in Fig.1, there are three dumps with the elevation from 1300m to 1520m and two open pits with the

elevation from 1150m to 1250m in the two ASTER-DEMs. The west dump formed in 2002, inter dump covered 356.66 hm2 and the south dump formed in 1985 covering 180.5 hm2. The eastern mining pit was formed following the mining direction between 2002 and 2006, which can be clearly visualized from the ASTER-DEM at 2006.

Accuracy Assessment

The reference DEM of 15m grid spacing was developed by digitizing contour lines from rectified topographic maps 1:50,000. As the different date among reference data and ASTER DEM, the changing area of open-pit was masked for accuracy assessment in case the error between ASTER DEMs and reference data was caused by the landform change in mining process. The non-change area or stable landform area was selected to assess the maximum (max), minimum (min) and mean elevation value between ASTER DEM and reference DEM.

The max elevation value of ASTER 2002 is 1552m, which is the same as reference data, while the max for ASTER 2006 is 77m higher. Besides, the min elevation values of ASTER 2002 and ASTER 2006 were 9m and 17m lower than the reference data. The mean elevation is 1369m of ASTER-DEM in 2002, which is 2m higher than reference data, as the mean elevation of ASTER-DEM in 2006 is 38m higher (Fig. 2a).

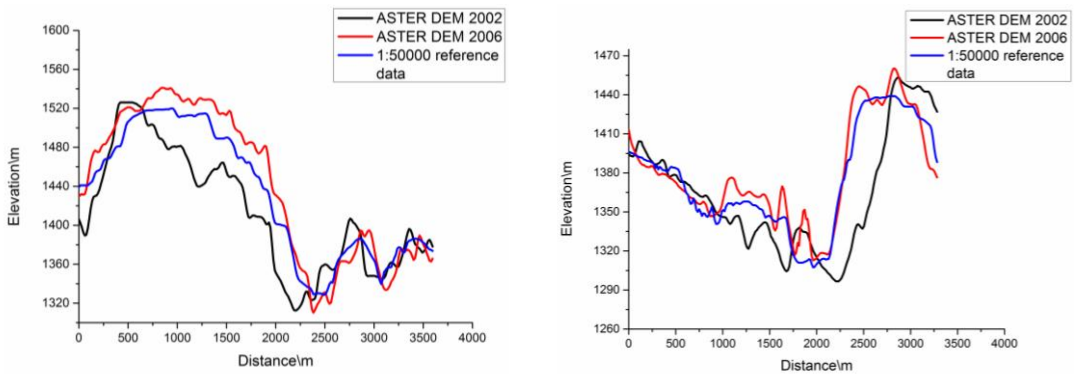


(a) (b)

FIG. 2 MAIN CALCULATED INDICES FOR ELEVATION FROM BOTH ASTER-DEM AND REFERENCE DATA (A); THE DISTRIBUTION MAP OF SAMPLE POINTS FOR ACCURACY ASSESSMENT IN STUDY AREA (B)

A number of check points were created according to the non-change landscape from aerial photos to assess the accuracy of ASTER-DEM of 2002 and 2006. About 70 check points were used to perform accuracy analysis between the DEMs and reference DEM. The RMSE was 25m for 2002 and 26m for 2006 by comparing the check points for the study area, while the mean elevation difference values were 9m for 2002 and -17m for 2006.

Two topographic profiles were developed from ASTER-DEM and reference data to provide both a quantitative and visual assessment of ASTER DEM quality, as shown in Fig. 3: one profile was generated from the N to S for the western dump (Fig. 3a), while the other profile was generated from W to E in the southern dump (Fig. 3b). The elevation of ASTER-DEM in 2006 and reference data reached the highest value at 1541m and 1519m respectively with the distance 800m and 850m, while the highest value of ASTER-DEM in 2002 was recorded at 1526m with the distance 500m to 600m. As shown in figure 3a, the elevation values of ASTER-DEMs and reference data decreased gradually from 850m to 2500m. The highest valley values occurred at 1312m, 1310m and 1329m for ASTER-DEM in 2002, ASTER-DEM in 2006 and reference data. The elevations changed gradually with two higher peak values from 2500m to 4000m. Conversely, profile W–E, which was taken across the southern dump, demonstrated a strong consistent between ASTER and reference data (Fig. 3b). The valley values occurred at 1297m, 1413m and 1396m for ASTER-DEM in 2002, ASTER-DEM in 2006 and reference data with the distance 2200m-2500m. After that, elevations changed greatly until the highest values were recorded at ASTER-DEMs and reference data. Then, the elevation decreased dramatically. Therefore, the ASTER DEMs and reference data had the similar valley values, peak values and changing trends. The accuracy of ASTER DEM can meet the need of the landform characteristic analysis from large surface mine area[11].

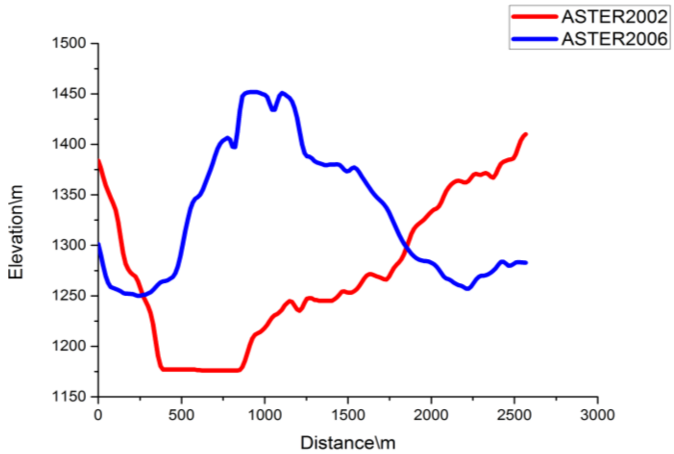


(a) (b)

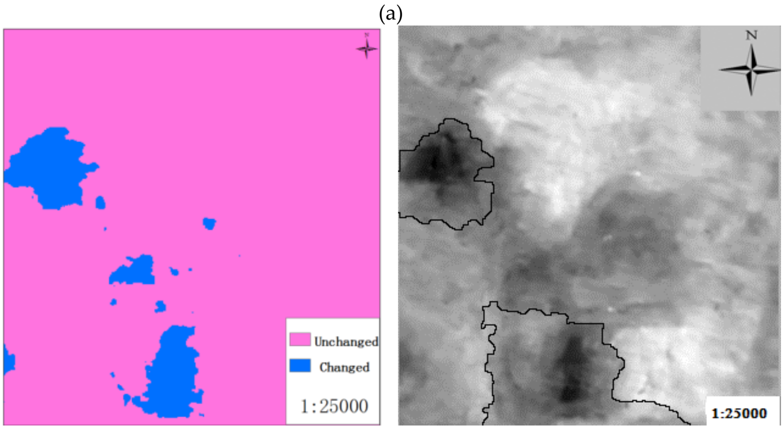
FIG. 3 PROFILE COMPARISONS BETWEEN ASTER DEM ELEVATIONS AND REFERENCE DATA. (A) PROFILE N–S; (B) PROFILE W–E.

Change Detection

The landform change area was automatically identified in vertical level using the methods of setting a threshold value based on different image (Fig. 4b, fig. 4 c). The topography change occurred in the location of two pits in 2002 and dumps in 2006. Topographic profiles were developed of two ASTER-DEMs through the western pits in 2002 to perform a visual analysis of the topography change (Fig. 4a). The elevation decreased dramatically from 1384m in 2002 and 1301m in 2006 to 1177m of 2002 and 2006 from 0m to 500m. As the pit was filled by the solid wasted sourced from mines in 2006 flowing the mining, the biggest difference was recorded while the distance was from 500 to 1000m, which showed the positive terrain and negative terrain. The landform change area in the horizontal level was automatically detected using the watershed transform method (Fig. 4a). In terms of the general shape, size and location, the change areas from two methods were similar and matched. The change areas were pits at 2002 and dumps at 2006, due to the exploiting-peeling-deserting unification of mining.



(a)



(b) (c)

FIG. 4 PROFILE COMPARISONS BETWEEN ASTER-DEMS IN 2002 AND 2006 (A) TOPOGRAPHIC CHANGE IN HORIZONTAL AND VERTICAL LEVEL: TOPOGRAPHIC CHANGE IN VERTICAL LEVEL(B); TOPOGRAPHIC CHANGE IN HORIZONTAL LEVEL(C).

Conclusion

This study demonstrated the use of ASTER-DEMs generated from stereo images to analyze the landform changing quantitatively for a large surface coal mine site. This study demonstrated that: the RMSEs in elevation are about 25m for ASTER DEM in 2002 and 26m for ASTER DEM in 2006. The trends of elevation curve between DEMs of ASTER and reference DEM are similar in horizontal level. Thus, the accuracy of ASTER DEMs can meet the need of landform characteristic analysis on large surface mine area. The area of topographic change can be identified automatically based on the different image by setting a threshold value and watershed transform method. Then, the positive and negative terrain features from topographic change results can directly describe the mining process, which can be used to calculate and predict the soil volume.

Therefore, the DEM based on ASTER stereo image can analyze the topographic feature quantitatively, such as the advantage of efficiency, extensiveness and low cost. It can provide a basis for the ecological reconstruction and land reclamation. A further study is necessary using field GPS data collection to increase the accuracy of DEM.

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